The potential health effects of taxing sugary drinks in Estonia – Supplementary Material

Methods

A mathematical simulation model was developed to estimate the effect of a SSB tax on the prevalence of overweight and obesity, three obesity-related diseases, health-adjusted life years and tax revenue over the lifetime of the population, using 2015 as the baseline year. The model was carried out in MS Excel (Microsoft Office 2010) with the add-in tool Ersatz (EpiGear, Version 1.32) for uncertainty analysis.

The work builds on prior research done by Dr Lennert Veerman.[1] Mathematical models were adapted to the Estonian context, using epidemiological, demographic, nutritional and sales data on (and from) Estonia.

Life table analysis

In a proportional multi-state lifetable (1) (Figure S1), health-adjusted life years (HALYs) gained by an intervention are evaluated as the difference in health-adjusted years of life lived between a population that mimics the population of interest in terms of SSB consumption and BMI, and an identical population that receives the intervention (SSB tax). Both populations have a BMI distribution that continues the upward trend observed in recent years until 2035, after which the BMI distribution stabilizes. Trends in the per capita consumption of SSBs have also been incorporated up to 2025, after which consumption was assumed stable (Figure 4). The intervention effects are superimposed on these trends. The health-adjusted years of life lived by each population are calculated by dividing each population into five-year age group cohorts (from age 15-19 to age 95+), and simulating each cohort in a life table until everyone has either died or reached 96 years of age.

Years of life lived by each cohort are adjusted at each age for time spent in poor health (‘disability’) due to disease or injury, using disability estimates for the Australian population (2). For modelled disease, the disability adjustment is calculated as the number of prevalent years lived with disability (pYLD) per prevalent case of disease. The age- and sex-specific probability of health loss due to disability from all other causes (i.e. those not specifically modelled) is calculated as the number of pYLD per capita for these conditions.

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[1] Veerman JL, Sacks G, Antonopoulos N, Martin J. The Impact of a Tax on Sugar-Sweetened Beverages on Health and Health Care Costs: A Modelling Study. PLoS One. 2016 Apr 13;11(4):e0151460; World Bank. Economic Policy Options to Address Overweight and Obesity in East Asia and the Pacific: The Role of Taxes and Trade. To be published in 2017.

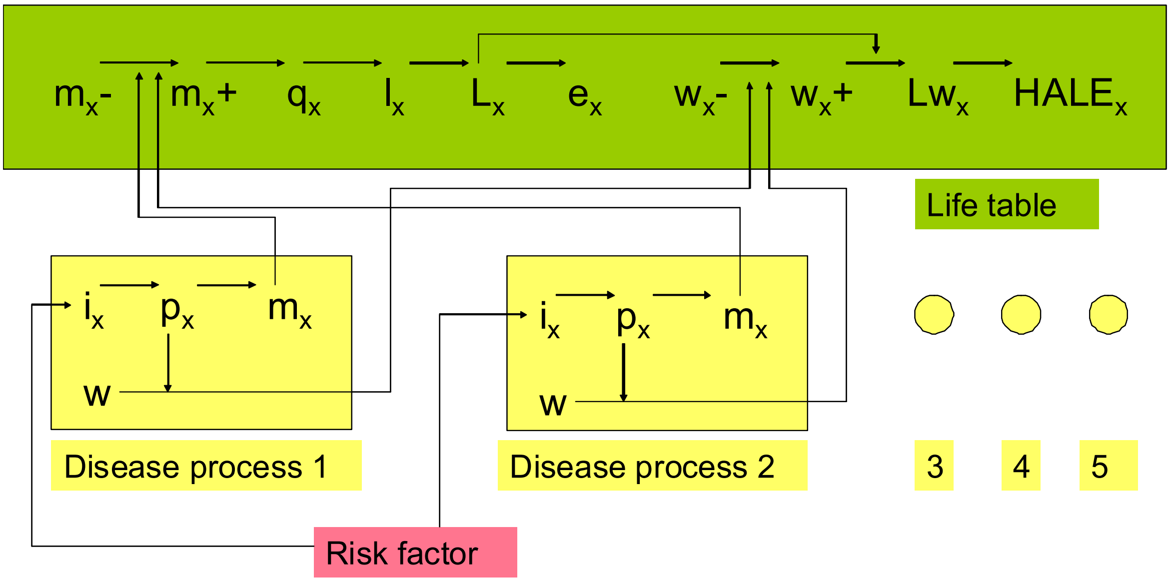

Figure S1: Schematic of a proportional multi-state lifetable, showing the interaction between disease parameters and lifetable parameters, where x is age, i is incidence, p is prevalence, m is mortality, w is disability-adjustment, q is probability of dying, l is number of survivors, L is life years, Lw is disability-adjusted life years and HALE is health-adjusted life expectancy, and where '-' denotes a parameter that specifically excludes modelled diseases, and '+' denotes a parameter for all diseases (i.e. including modelled diseases).

Disease models

Overweight and obesity increase the risk of stroke, ischemic heart disease and diabetes mellitus. Each of these diseases is modelled explicitly using a set of differential equations that describe the transition of people between four states (healthy, diseased, dead from the disease, and dead from all other causes), with transition of people between the four states based on rates of mortality, incidence, case fatality and remission (Figure S2) (4).

Epidemiological data inputs to the disease models are derived from the Estonian source, with the aid of DISMOD-II (4) to derive data not explicitly reported (e.g. case fatality and prevalence from incidence and mortality rates).

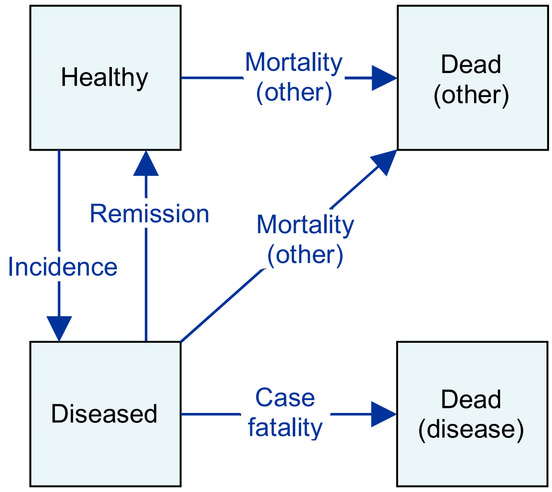

Figure S2: Each disease is modelled by a conceptual model with four states (healthy, diseased, dead from the disease, and dead from all other causes) and transition hazards between states of incidence, remission, case fatality and mortality from all other causes (after Barendregt et al.(4))

Effect of changes in risk factor exposure on disease frequency

The health benefits of an intervention are modelled as a reduction in incidence of each obesity-related disease. Intervention combinations (such as the effect on diabetes incidence of changes in BMI and changes in SSB consumption directly) are assumed to have a multiplicative effect (Equation 1).

$$I' = I\left(1 - \mathrm{PIF}_1\right)\left(1 - \mathrm{PIF}_2\right)\ldots\left(1 - \mathrm{PIF}_n\right) \qquad \text{(Equation 1)}$$

where:

I is the incidence of disease (e.g. ischaemic heart disease) in the population (by age and sex);

I' is the new incidence of disease (e.g. ischaemic heart disease) when an intervention is implemented; and

PIF_i is the potential impact fraction (PIF) for interventions *1* to *n*.

Each potential impact fraction (PIF) is derived from three key parameters: the population prevalence of overweight and obesity, the relative risks of obesity-related diseases, and the change in body mass due to an intervention. The prevalence of overweight and obesity is derived from the distribution of BMI in the Estonian National Dietary Survey in 1997 and 2013-2014 (Table S2). Relative risks of disease per unit increase in BMI (Table A8) are drawn from meta-analyses carried out for the Global Burden of Disease study (3).

The intervention impact on disease is quantified by the continuous version of the PIF calculation ('distribution shift'; Equation 2) (4).

$$PIF = \frac{\int_l^h RR(x)P(x)dx - \int_l^h RR(x)P^*(x)dx}{\int_l^h RR(x)P(x)dx} \qquad \text{(Equation 2)}$$

Where RR(x) is the risk function, P(x) is the original risk factor distribution, P*(x) the risk factor distribution after the intervention, and l and h are the integration boundaries.

Supplementary Tables and Figures

Table S1: Beverage consumption by age and sex at baseline

Source: The Estonian National Dietary Survey 2013-2014

Consumption l/day/person						
	MEN			WOMEN		
Age Group	**Soft drinks**	**Juice**	**Milk**	**Soft drinks**	**Juice**	**Milk**
0-5	0.10	0.05	0.18	0.10	0.04	0.18
5-9	0.11	0.05	0.28	0.14	0.04	0.21
10-14	0.17	0.06	0.25	0.11	0.04	0.22
15-19	0.21	0.06	0.25	0.12	0.04	0.15
20-24	0.17	0.05	0.19	0.10	0.05	0.12
25-29	0.17	0.05	0.19	0.10	0.05	0.12
30-34	0.14	0.04	0.18	0.06	0.03	0.13
35-39	0.14	0.04	0.18	0.06	0.03	0.13
40-44	0.06	0.06	0.17	0.04	0.03	0.11
45-49	0.06	0.06	0.17	0.04	0.03	0.11
50-54	0.05	0.03	0.17	0.03	0.02	0.10
55-59	0.05	0.03	0.17	0.03	0.02	0.10
60-64	0.05	0.04	0.19	0.03	0.03	0.13
65-69	0.05	0.04	0.19	0.03	0.03	0.13
70-74	0.05	0.03	0.17	0.02	0.01	0.12
75-79	0.05	0.03	0.17	0.02	0.01	0.12
80-84	0.05	0.03	0.17	0.02	0.01	0.12
85-89	0.05	0.03	0.17	0.02	0.01	0.12
90+	0.05	0.03	0.17	0.02	0.01	0.12

Table S2 Distribution of BMI data

2014			Body mass index (kg/m^2)	
Sex	Age range	N	Mean	Standard deviation
Female	18-29	329	22.7707	4.1617
Female	30-39	318	24.5655	5.0683
Female	40-49	335	27.0677	5.9124
Female	50-59	296	27.9577	5.5358
Female	60-69	381	29.8126	6.614
Female	70-74	147	30.0001	6.5764
Male	18-29	212	24.3769	4.2182
Male	30-39	169	26.8254	5.039
Male	40-49	136	27.1179	4.2919
Male	50-59	148	28.2372	4.6467
Male	60-69	168	27.9469	4.7245
Male	70-74	74	27.6086	5.1743

1997			Body mass index (kg/m^2)	
Sex	Age range	N	Mean	Standard deviation
Female	19-34	305	21.5	2.9
Female	35-49	196	24.2	4.2
Female	50+	128	26.3	4
Male	19-34	258	24.5	3.8
Male	35-49	174	25.5	3.5
Male	50+	93	25.9	3.5

Table S3: Prevalence of underweight, normal weight, overweight and obesity in Estonia in 2014 (Source: The Estonian National Dietary Survey)

		Underweight	Normal weight	Overweight	Obese
Men	**All age groups**	2.6	45.8	35.9	15.8
	2-5	1.3	90.7	6.9	1.1
	6-9	1.4	67	13.1	18.5
	10-13	3	60.5	19.8	16.7
	14-17	2.5	69.4	14.7	13.4
	18-24	3.5	65.5	24.6	6.4
	25-29	4.1	44	37.3	14.6
	30-34	0	48.9	36.1	14.9
	35-39	2.2	33.7	44.2	20

	40-44	0	34	53.9	12
	45-49	0	23.4	50.9	25.6
	50-54	0	27.7	45	27.3
	55-59	0	14	61.2	24.8
	60-64	0.4	21.8	51.4	26.4
	65-69	15.3	57.3	25.7	1.7
	70-74	14.7	63.8	15.6	5.8
Women	**All age groups**	4.3	52.8	25.3	17.6
	2-5	3.1	90.9	5.5	0.6
	6-9	2.2	68.5	20.4	8.8
	10-13	3.2	65.9	21.5	9.3
	14-17	1.4	79.5	16	3.1
	18-24	7.5	76.4	9.7	6.3
	25-29	8	68.4	18	5.6
	30-34	6.1	60.2	22.6	11.2
	35-39	3.4	52.9	31	12.7
	40-44	0.5	44.8	35.4	19.3
	45-49	2	39.9	29	29.1
	50-54	0.9	40.9	37.4	20.8
	55-59	0.5	26	33.4	40.1
	60-64	1	24.1	38.1	36.8
	65-69	12.1	44	22.6	21.3
	70-74	11.7	44.3	24.4	19.7

Table S4: Relative risk of incident disease as a function of BMI

Age	**Diabetes**	**Ischemic heart disease**	**Ischemic stroke**
	Mean (95 % confidence interval)	Mean (95 % confidence interval)	Mean (95 % confidence interval)
25-29 years	4.84 (3.45, 6.63)	1.88 (1.70, 2.08)	1.85 (1.76, 1.93)
30-34 years	4.39 (3.20, 5.91)	1.81 (1.64, 1.99)	1.78 (1.70, 1.85)
35-39 years	3.99 (2.97, 5.27)	1.74 (1.59, 1.91)	1.71 (1.65, 1.78)
40-44 years	3.62 (2.75, 4.7)	1.68 (1.54, 1.82)	1.65 (1.59, 1.71)
45-49 years	3.29 (2.55, 4.19)	1.61 (1.49, 1.74)	1.59 (1.54, 1.64)
50-54 years	2.99 (2.37, 3.74)	1.55 (1.45, 1.67)	1.53 (1.49, 1.58)
55-59 years	2.72 (2.20, 3.33)	1.49 (1.40, 1.60)	1.48 (1.44, 1.52)
60-64 years	2.47 (2.04, 2.97)	1.44 (1.36, 1.53)	1.42 (1.39, 1.46)
65-69 years	2.24 (1.89, 2.65)	1.38 (1.31, 1.46)	1.37 (1.34, 1.40)
70-74 years	2.04 (1.75, 2.36)	1.33 (1.27, 1.4)	1.32 (1.29, 1.35)
75-79 years	1.85 (1.63, 2.11)	1.28 (1.23, 1.34)	1.27 (1.25, 1.29)
80+ years	1.61 (1.46, 1.77)	1.21 (1.17, 1.25)	1.20 (1.19, 1.22)

Table S5: Market share of the main products (2016)

Product	**Product 1st**					**Product 2nd**					**Product 3rd(Carbonates: 3rd + 4 th)**				
	Brand	Market share (%)	Pack size (ml)	Price per pack	Cost per litre	Brand	Market share (%)	Pack size (ml)	Price per pack	Cost per litre	Brand	Market share (%)	Pack size (ml)	Price per pack	Cost per litre
Carbonates	Coca-cola	17.30	330	0.50	1.51	Diet Coke	8.80	330	0.55	1.67	Sprite + Fanta	16.4	330	0.54	1.64
Concentrates*	Kannujook	29.40	5,000	1.59	0.32	Ambrosia	17.10	2,500	1.35	0.54	Aura	10.10	3,750	1.59	0.42
Juice	Aura (Olvi Oyj)	55.27	500	0.75	1.50	Põltsamaa	21.48	200	0.38	1.90	Gutta	17.67	1,000	1.18	1.18
RTD Coffee	Rauch	44.50	250	0.69	2.76	Saare Latte	25.80	200	0.69	3.45	Hustler Coffee	0.00	0.00	0.00	0.00
RTD tea	Nestea	82.00	500	0.85	1.70	Lipton	10.90	1,500	1.28	0.85	Vichy	5.80	1,500	0.45	0.30
Energy drink	Arctic (Olvi Oyj)	18.30	330	1.19	3.61	Red Bull	11.10	250	1.39	5.56	Dynami:t	10.30	500	0.59	1.18

Table S6: The calculation of average retail price

Product	Total market share (%) of the main brands	Weighted average pre-tax price per litre	Total sale of SSBs in 2016 (million litre)	Weighted average price
Carbonates	42.50	1.59	62.30	
Concentrates	56.60	0.40	14.00	
Juice	94.42	1.53	17.95	
RTD coffee	70.30	3.01	0.00	1.57
RTD tea	98.70	1.52	2.50	
Energy drink	39.70	3.52	8.00	

Table S7: Number of cases of obesity and overweight prevented in adults*

		Obesity	Overweight
Scenario 1	Males	1026 (1405-666)	356 (496-226)
	Females	546 (744-358)	242 (331-156)
Scenario 2	Males	1795 (2452-1150)	630 (877-407)
	Females	954 (1296-636)	425 (593-274)
Scenario 3	Males	1795 (2807-1213)	711 (1022-414)
	Females	1079 (1493-660)	481 (674-291)
Scenario 4*	Males	1326 (891-1785)	
	Females	707 (478-951)	

*for scenario 4 only obesity cases are shown

Table S8: Number of cases of obesity and overweight prevented in children*

		Obesity	Overweight
Scenario 1	Boys	246 (336-164)	232 (348-114)
	Girls	210 (286-141)	215 (1098-797)
Scenario 2	Boys	433 (589-288)	641 (849-426)
	Girls	366 (483-242)	775 (1036-513)
Scenario 3	Boys	482 (672-308)	715 (978-463)
	Girls	408 (548-264)	863 (1188-565)
Scenario 4*	Boys	308 (208-417)	
	Girls	261 (175-350)	

*for scenario 4 only obesity cases are shown

Table S9: Number of new cases prevented in type 2 diabetes, heart disease and stroke*

Note: the deaths cannot be added, since some of the deaths among people with diabetes would be via heart disease and stroke, so that adding would result in double counting of these deaths.

Basecase		Scenario 1	Scenario 2	Scenario 3	Scenario 4*
Diabetes	New cases	1228 (1685-839)	2110 (2906-1396)	2462 (3395-1590)	1583 (1064-2192)
	Deaths	333 (458-226)	572 (785-377)	668 (921-433)	
Heart disease	New cases	161 (215-107)	281 (379-190)	316 (431-196)	206 (140-274)
	Deaths	41 (57-27)	75 (101-50)	84 (116-51)	
Stroke	New cases	77 (107-49)	135 (189-88)	152 (210-93)	99 (66-138)
	Deaths	14 (19-9)	24 (34-16)	27 (38-16)	

*for scenario 4 only new cases are shown

Table S10: Number of lifetime HALYs gained over the first 25 years following the introduction of a tax; tax revenue in the first year of tax implantation (95% uncertainty interval in brackets)

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Male	1610 (770-1660)	2790 (1380-2930)	3210 (1550-3410)	2071 (1463-2762)
Female	1180 (1120-2150)	2080 (1960-3750)	2420 (2110-4310)	1597 (1078-2244)
Total	2790 (1940-3710)	4870 (3430-6510)	5620 (3760-7590)	3669 (2599-4824)

Table S11: Monetized value (Euro) of HALYs

	Scenario 1	Scenario 2	Scenario 3
Male	25,032,280 (11971960-25809680)	43,378,920 (21456240-45555640)	49,909,080 (24099400-53018680)
Female	18,346,640 (17413760-33428200)	32,339,840 (30474080-58305000)	37,626,160 (32806280-67011880)
Total	43,378,920 (30163120-57683080)	75,718,760 (53329640-101217480)	87,379,760 (58460480-118009320)

Table S12: One-way sensitivity analysis

	Scenario 1	Scenario 2	Scenario 3
Base case	2787 (1936-3713)	4869 (3432-6510)	5622 (3758-7592)
No discounting	8406 (5824-11179)	14792 (9941-19890)	16918 (11660-22785)
2% discounting	3890 (2552-5206)	6824 (4762-9162)	7830 (5360-10410)
5% discounting	1562 (1062-2111)	2760 (1929-3680)	3145 (2153-4292)
10 cents lower tax	1484 (1016-2006)	3862 (2698-5095)	4810 (3284-6447)
10 cents higher tax	3860 (2573-5168)	5749 (3935-7700)	6277 (4288-8506)

Tax pass-on 80%	2299 (1627-3111)	4134 (2818-5504)	4819 (3297-6491)
Tax pass-on 120%	3262 (2233-4417)	5623 (3868-7552)	6309 (4292-8599)
Average price from largest packs	4695 (3139-6334)	7519 (5064-10143)	8175 (5102-11148)
No cross price elasticities applied	4107 (3351-4988)	7188 (5859-8703)	8359 (6812-10066)
10% higher average price	2561 (1731-3446)	4540 (3141-6090)	5285 (3561-7173)
All soft drinks replaced with water	120501 (104595-136417)	121889 (106904-138009)	120709 (106146-137419)
Reformulation		6423 (5412-7542)	
Reformulation + consumption change		8334 (6891-9941)	
Euromonitor sales data	9459 (7555-11615)	16355 (13112-19938)	18909 (15173-23004)

References

1. Barendregt JJ, Van Oortmarssen GJ, Van Hout BA, Van Den Bosch JM, Bonneux L. Coping with multiple morbidity in a life table. Math Popul Stud. 1998;7(1):29-49, 109.
2. Begg S, Vos T, Barker B, Stevenson C, Stanley L, Lopez AD. The Burden of Disease and Injury in Australia. Canberra: AIHW; 2007.
3. Murray CJ, Atkinson C, Bhalla K, Birbeck G, Burstein R, Chou D, et al. The state of US health, 1990-2010: burden of diseases, injuries, and risk factors. JAMA. 2013;310(6):591-608.
4. Barendregt JJ, van Oortmarssen GJ, Vos T, Murray CJ. A generic model for the assessment of disease epidemiology: the computational basis of DisMod II. Population Health Metrics. 2003;1(1):4.